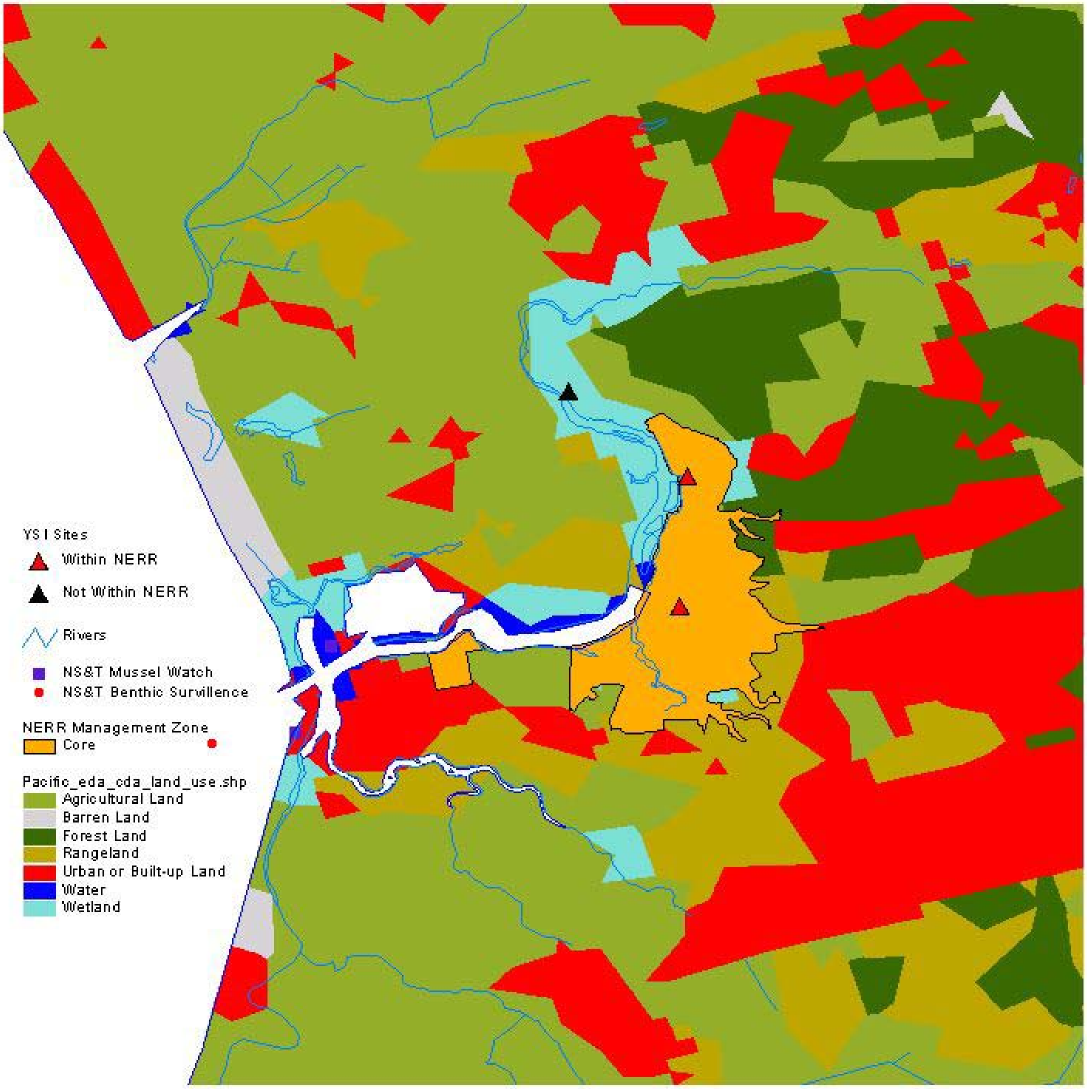
Elkhorn Slough



Elkhorn Slough, Azevedo Pond (ELKAP)

Characterization (Latitude = 36°50'50"N; Longitude = 121°45'16" W)
Azevedo pond is 53 m long (mainstream linear dimension), has an average depth of 0.7 m MHW, and an average width of 8 m. At the sampling site, the depth is 1 m MHW and the width is 6 m. This site is a tidal pond connected to the main channel of Elkhorn Slough by a culvert. The bottom sediment is organic rich silt. Extensive mats of macroalgae (*Ulva* sp. and *Enteromorpha* sp.) occur within the pond. The dominant marsh vegetation near the sampling site is pickleweed. The dominant upland vegetation includes strawberry and flower fields and grasslands. Upland land use near the sampling site is agriculture. Azevedo Pond has a very narrow (~ 3 m) fringe of marsh with grassland slopes and farmed terraces. The farm surrounding the pond is part of a project to develop best management practices and new growing techniques.

Descriptive Statistics
Thirty-eight deployments were made at this site between Feb 1996 and Dec 1998, with equal coverage in all seasons (Figure 4). Mean deployment duration was 26.8 days. Only three deployments (Mar, May, Nov 1996) were less than 20 days.

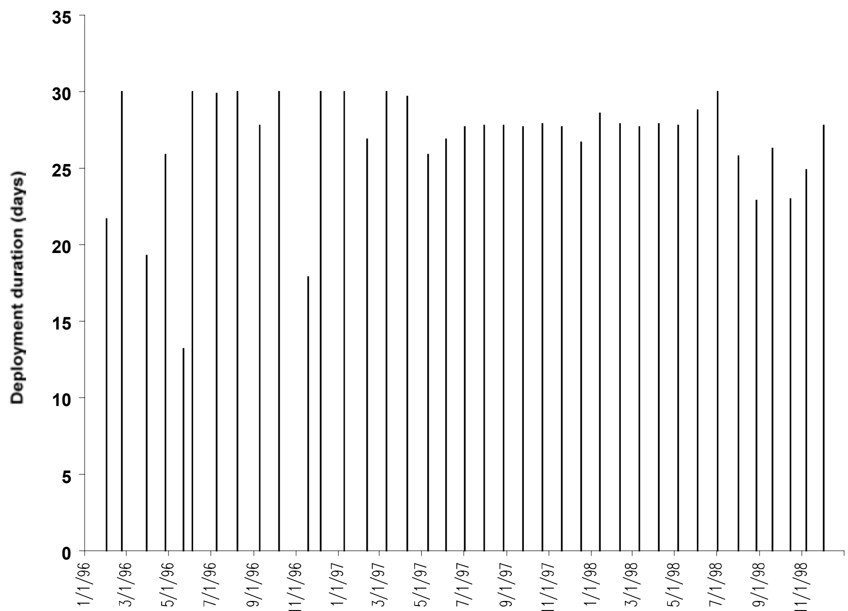


Figure 4. Elkhorn Slough, Azevedo Pond deployments (1996-1998)

Ninety-two percent of annual depth data were included in analyses (90% in 1996, 89% in 1997, and 98% in 1998). Sensors were deployed at a mean depth of 0.3 m below the water surface. Minor fluctuations (< 0.5 m) in water depth were evident from scatter plots for daily and bi-weekly cycles throughout most of 1996-1998, with stronger fluctuations (≥ 1 m) observed between Nov 1997 – Feb 1998 and again in Nov-Dec 1998. Harmonic regression analysis attributed 57% of depth variance to interaction between 12.42 hour and 24 hour cycles. Twenty-five percent of depth variance was attributed to 24-hour cycles and 18% of depth variance was attributed to 12.42 hour cycles.

Ninety-two percent of annual water temperature data were included in analyses (90% in 1996, 89% in 1997, and 98% in 1998). Water temperature followed a seasonal cycle, with mean water temperatures 13-15°C in winter and 20-22°C in summer (Figure 5). Minimum and maximum water temperatures between 1996-1998 were –1.3°C (Dec 1998) and 35.6°C (Aug 1998), respectively. Minimum water temperature below 5°C was only recorded on three occasions (Jan, Dec 1997 and Dec 1998). Maximum water temperature above 30°C was frequently observed in summer. Scatter plots suggest strong fluctuations in daily (1-4°C) and bi-weekly (5-10°C) water temperature in winter, summer, and fall, with even stronger fluctuations (5-15°C) in daily and bi-weekly cycles in spring. Harmonic regression analysis attributed 86% of temperature variance to 24 hour cycles, 12% of temperature variance to interaction between 12.42 hour and 24 hour cycles, and 2% of variance to 12.42 hour cycles.

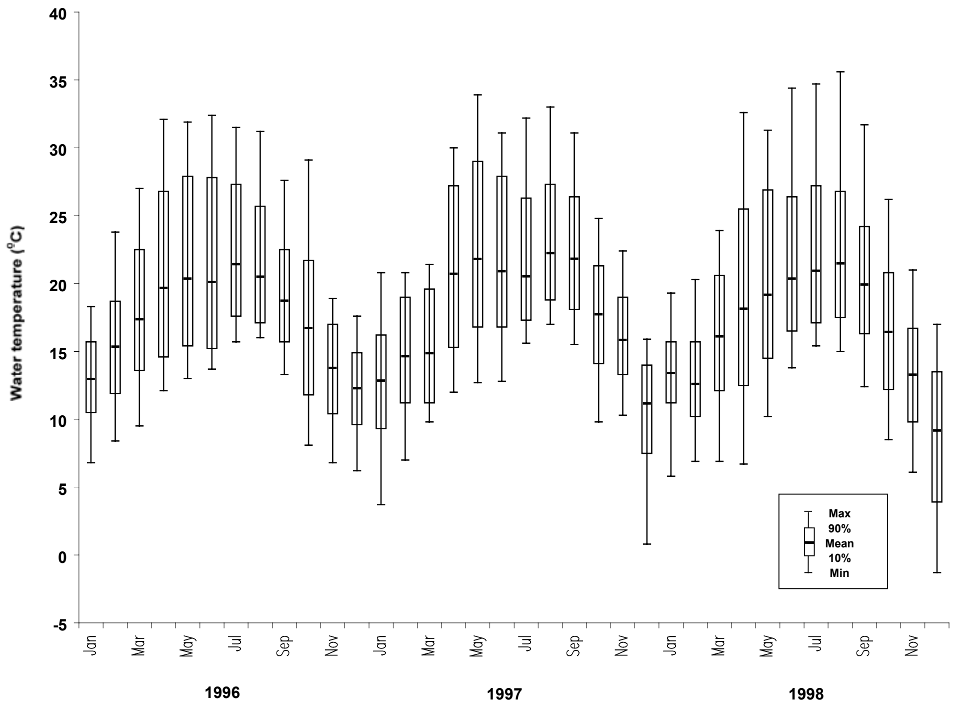


Figure 5. Water temperature statistics for Azevedo Pond, 1996-1998.

Ninety percent of annual salinity data were included in analyses (84% in 1996, 89% in 1997, and 97% in 1998). Mean salinity followed a seasonal cycle; however, large variances were associated with mean salinity values in winter and spring (Figure 6). Mean salinity was 20-22 ppt in winter 1996-1997 and 16-18 ppt in winter/spring 1998 (an El Nino year). Mean salinity in summer 1996-1998 was 33-35 ppt. Minimum and maximum salinity in 1996 was 9.1 ppt and 38.8 ppt, respectively, compared to minimum (0.5 ppt) and maximum (39.2 ppt) salinity between 1997-1998. Scatter plots suggest moderate fluctuations (1-2 ppt) in salinity at daily intervals and even stronger fluctuations (5 ppt) in salinity at bi-weekly intervals. In winter/spring, fluctuations in bi-weekly salinity are comparable to annual fluctuations (15-30 ppt) in salinity. Harmonic regression analysis revealed that 53% of salinity variance was attributed to interaction between 12.42 hour and 24 hour cycles, 29% of salinity variance to 24 hour cycles, and 18% of salinity variance to 12.42 hour cycles.

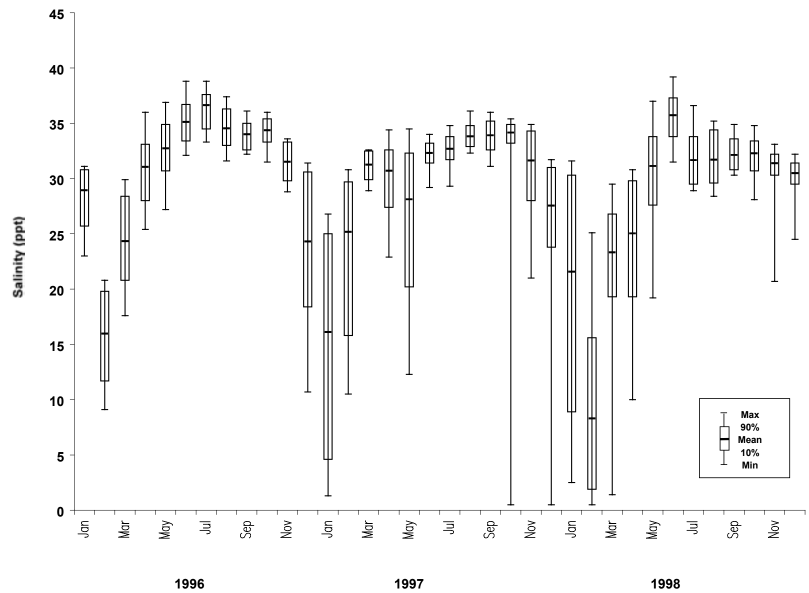


Figure 6. Salinity statistics for Azevedo Pond, 1996-1998.

Eighty-six percent of annual dissolved oxygen data (% saturation) were included in analyses (83% in 1996, 79% in 1997, and 96% in 1998). Mean DO below 50% saturation was never observed and mean DO above 100% saturation was observed on only three occasions (Mar 1996, Apr-May 1997). Minimum DO frequently approached 0% saturation and maximum DO exceeded 350% saturation on three occasions (Aug 1996, Apr-May 1997). Hypoxia was regularly observed in all seasons/years (except winter 1998) and, when present, hypoxia persisted for 18% of the first 48 hours post-deployment on average (Figure 7). Supersaturation was also regularly observed in all seasons/years and, when present, supersaturation persisted for 28% of the first 48 hours post-deployment on average. Scatter plots suggest strong fluctuations (60-100%) in percent saturation throughout 1996-1998, with even stronger fluctuations (>200%) in summer and fall. Harmonic regression analysis attributed 78% of DO variance to 24 hour cycles, 20% of DO variance to interaction between 24 hour and 12.42 hour cycles, and 2% of DO variance to 12.42 hour cycles.

Photosynthesis/Respiration

Almost all (97%) of the data used to calculate the metabolic rates fit the basic assumption of the method (heterogeneity of water masses moving past the sensor) and were used to estimate net production, gross production, total respiration and net ecosystem metabolism (Table 11). Instrument drift during the duration of the deployments was not a significant problem at this site. Total respiration exceeded gross production at Azevedo Pond; thus, net ecosystem metabolism and P/R ratio indicated that this is a heterotrophic site (Figure 8). Temperature was significantly ($p<0.05$) correlated with gross production, total respiration and net ecosystem metabolism. Gross production and respiration increased as temperature increased, while net ecosystem metabolism became more autotrophic as temperatures increased. Salinity was significantly ($p<0.05$) correlated with gross production, total respiration, but not net ecosystem metabolism. Gross production and respiration were higher at higher salinity. Metabolic rates strongly followed a seasonal pattern with the highest rates during summer months and the lowest rates during the winter rainy season when temperature and salinity were low.

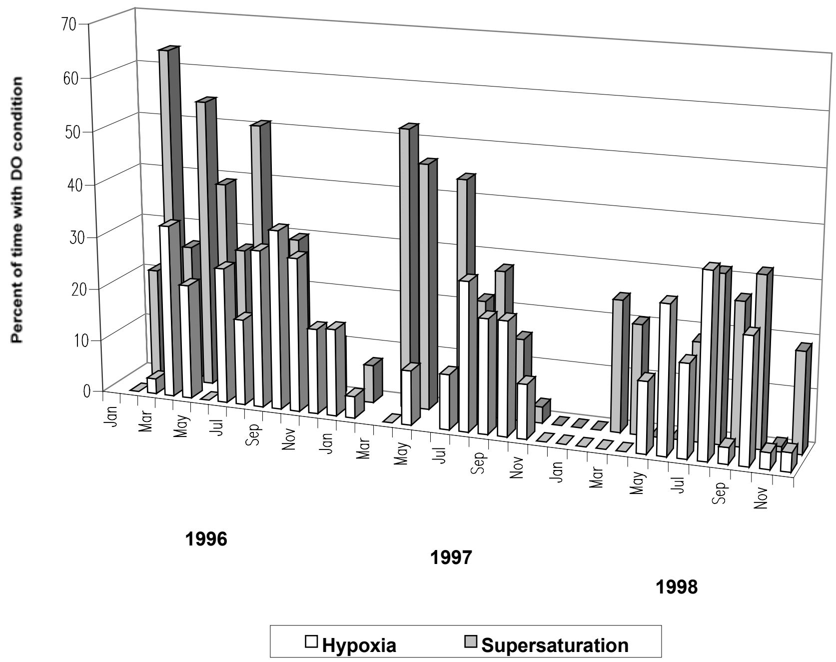


Figure 7. Dissolved oxygen extremes at Azevedo Pond, 1996-1998.

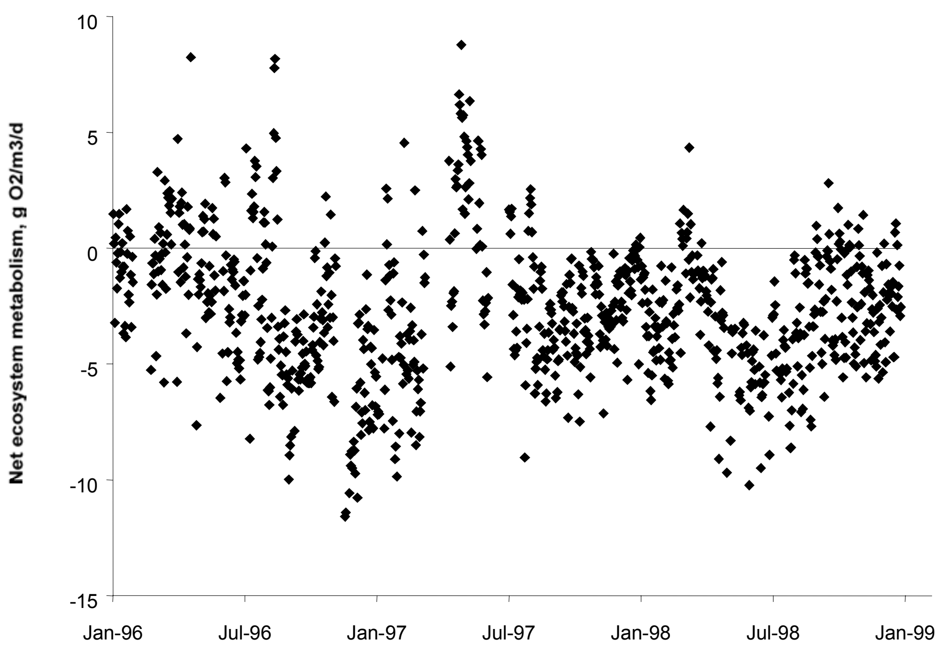


Figure 8. Net metabolism at Azevedo Pond, 1996-1998.

Table 11. Summary of metabolism data and statistics at Azevedo Pond, 1996-1998.

Azevedo Pond	mean	s.e.
Water depth (m)	0.7	
Net production $gO_2/m3/d$	5.83	0.19
Gross production $gO_2/m3/d$	15.56	0.32
Total respiration $gO_2/m3/d$	18.80	0.27
Net ecosystem metabolism g $O_2/m3/d$	-3.23	0.1
Net ecosystem metabolism g C/m2/y	63	
P/R	0.83	
Statistical results		
Drift – paired t-test		
Gross production	ns	
Total respiration	ns	
Net ecosystem metabolism	ns	
Percent useable observations	97%	
Paired t-test on gross production and total respiration	$p < 0.001$	
Correlation coefficient	Temperature	Salinity
Gross production	0.48	0.39
Total respiration	0.52	0.46
Net ecosystem metabolism	0.09	ns

Elkhorn Slough, South Marsh (ELKSM)

Characterization (Latitude = 36°49'11"N; Longitude = 121°44'13" W)
South Marsh is 1.5 km long (mainstream linear dimension), has an average depth of 2 m MHW, and an average width of 25 m. At the sampling site, the depth is 2 m MHW and the width is 27 m. This site is a tidal creek in a restored marsh that is separated from the main channel of Elkhorn Slough by a railroad line, roughly 800 m from the monitoring site. Tidal flushing occurs between the marsh and the main channel near the Railroad Bridge. Creek bottom habitats are predominantly silt-clay. The adjacent inter-tidal mudflats are often colonized by macroalgae such as *Ulva* sp. and *Enteromorpha* sp. The dominant marsh vegetation near the sampling site is *Salicornia* sp. The dominant upland vegetation includes a variety of non-native grasses and oak woodlands. The major runoff to this site is from grasslands and uplands on the Reserve. South Marsh is relatively un-impacted by anthropogenic influences except for inputs of agricultural runoff from the main channel of the slough or through the Reserve.

Descriptive Statistics
Thirty-six deployments were made at this site between Jan 1996 and Nov 1998, with equal coverage during all seasons (Figure 9). Mean deployment duration was 27.7 days. Only one deployment (Sep 1996) was less than 20 days.

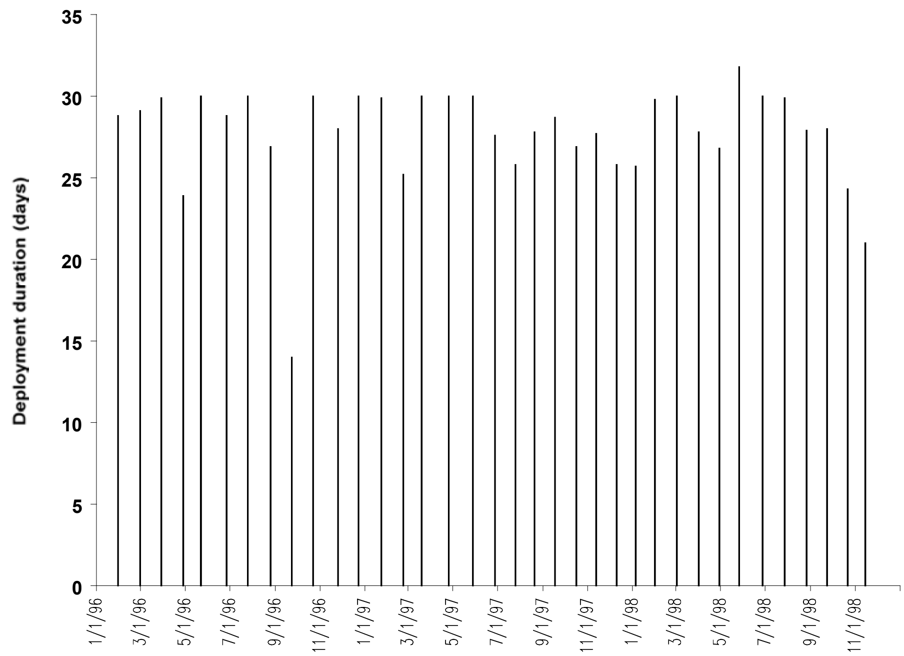


Figure 9. Elkhorn Slough, South Marsh deployments (1996-1998).

Ninety percent of annual depth data were included in analyses (92% in 1996, 86% in 1997, and 91% in 1998). Sensors were deployed at a mean depth of 1.4 m below the water surface. Strong fluctuations (1-2 m) in water depth were evident from scatter plots. Harmonic regression analysis attributed 55% of depth variance to 12.42 hour cycles, 26% of depth variance to 24 hour cycles, and 19% of depth variance to interaction between 12.42 hour and 24 hour cycles.

Ninety percent of annual water temperature data were included in analyses (92% in 1996, 86% in 1997, and 91% in 1998). Water temperature followed a seasonal cycle, with mean water temperatures 12-14°C in winter (except for Dec 1998, mean = 10°C) and 18-20°C in summer (Figure 10). Minimum and maximum water temperatures between 1996-1998 were 5.5°C (Dec 1998) and 24.4°C (Sep 1997), respectively. Water temperature below 10°C was infrequently observed (Jan, Mar 1996; Dec 1997, 1998) and temperatures above 25°C were never observed. Scatter plots suggest moderate fluctuations (1-2°C) in daily temperatures and strong (2-5°C) fluctuations in bi-weekly temperatures throughout most of the year; however, 5-10°C fluctuations in water temperature at daily and bi-weekly intervals were regularly observed in spring. Harmonic regression attributed 49% of temperature variance to 12.42 hour cycles, 32% of temperature variance to interaction between 12.42 hour and 24 hour cycles, and 19% of temperature variance to 24 hour cycles.

Ninety percent of annual salinity data were included in analyses (92% in 1996, 86% in 1997, and 91% in 1998). Mean salinity followed a seasonal cycle; however, large variances were associated with salinity in winter (Figure 3). Mean salinity in winter/spring was between 26-30 ppt and mean salinity in summer/fall was between 30-34 ppt. Minimum and maximum salinity observed between 1996-1998 was 8.3 ppt (Feb 1998) and 39.2 (Jun 1998), respectively. Scatter plots indicated minor fluctuations (1-2 ppt) in daily salinity and moderate fluctuations (2-5 ppt) in bi-weekly salinity throughout the year, except for large variation (≥ 15 ppt) during at least one month each winter.

Harmonic regression analysis attributed 38% of salinity variance to both 12.42 hour cycles and interaction between 12.42 hour and 24 hour cycles, and 24% of salinity variance to 24 hour cycles.

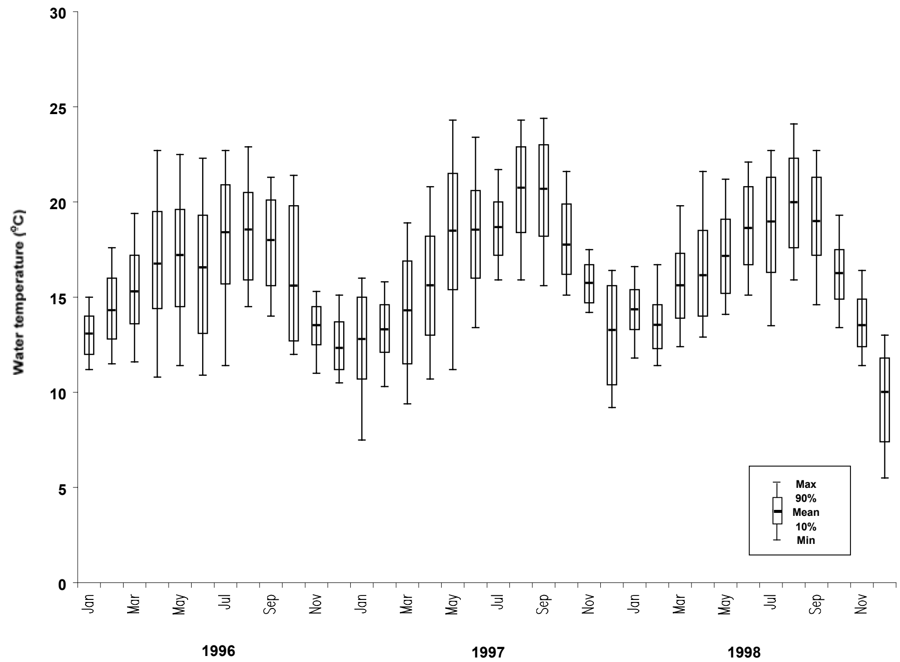


Figure 10. Water temperature statistics for South Marsh, 1996-1998.

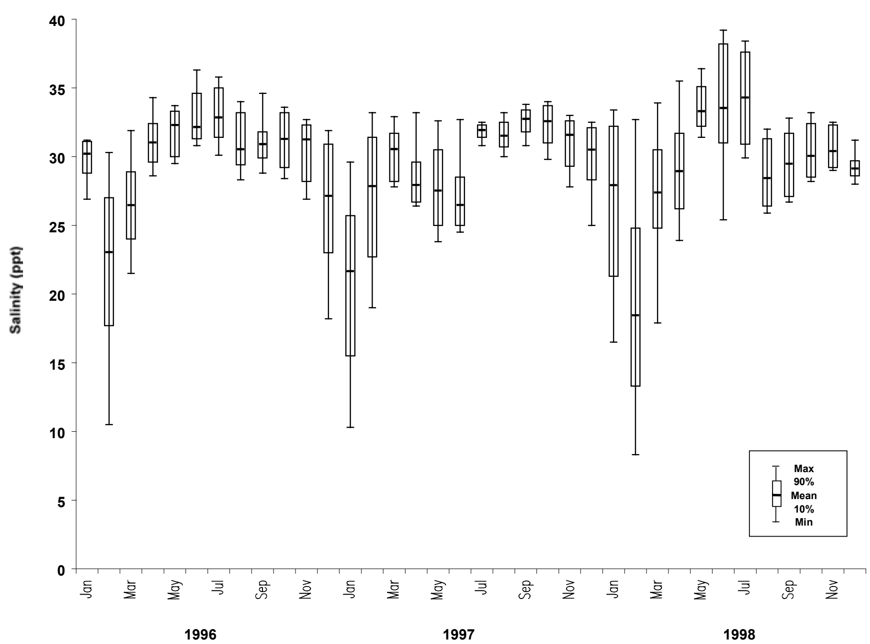


Figure 11. Salinity statistics for South Marsh, 1996-1998.

Sixty-five percent of annual dissolved oxygen (% saturation) data were included in analyses (82% in 1996, 43% in 1997, and 70% in 1998). Mean DO below 50% saturation was only observed on two occasions (Apr 1996, Mar 1997) and mean DO above 100% saturation was also only observed on two occasions (Feb, Mar 1998). Mean DO was typically 60-100% year round. Minimum DO approached 0% saturation on several occasions (Mar-Apr 1996 and Feb-Mar, May, Oct 1997) and maximum DO exceeded 200% saturation on one occasion (Nov 1996). Hypoxia was observed on two occasions (Oct 1996, Feb 1997) and, when present, hypoxia persisted for 11.6% of the first 48 hours post-deployment on average (Figure 12). Supersaturation was observed on several occasions (most notably Mar-Apr 1996 and Feb 1998) and, when present, supersaturation persisted for 16% of the first 48 hours post-deployment on average. Scatter plots suggest that percent saturation regularly fluctuated by 20-60% saturation over daily and bi-weekly intervals in 1996 and 1998 (except spring in both years), with even stronger fluctuations (60-100% sat) recorded for most of 1997. Harmonic regression analysis attributed 51% of DO variance to 24 hour cycles, 35% of DO variance to interaction between 12.42 and 24 hour cycles, and 14% of DO variance to 12.42 hour cycles.

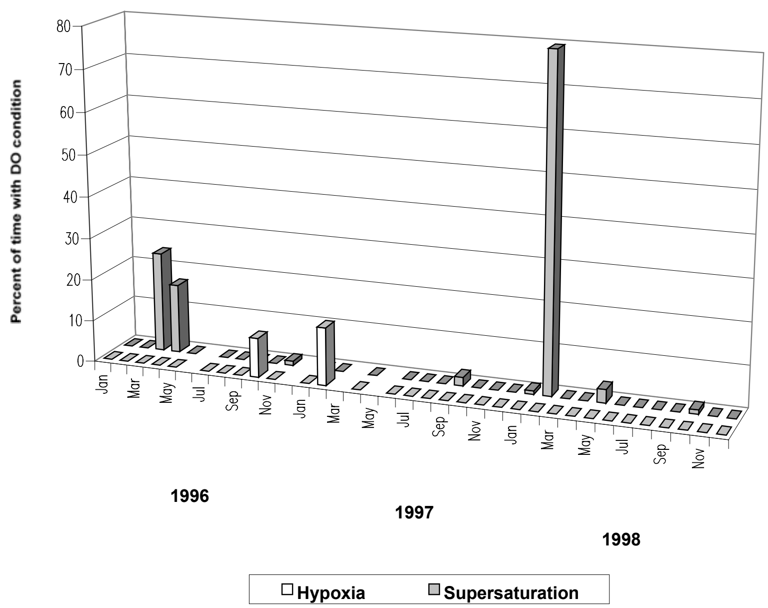


Figure 12. Dissolved oxygen extremes at South Marsh, 1996-1998.

Photosynthesis/Respiration

Over four fifths (88%) of the data used to calculate the metabolic rates fit the basic assumption of the method (heterogeneity of water masses moving past the sensor) and were used to estimate net production, gross production, total respiration and net ecosystem metabolism (Table 12). Instrument drift during the duration of the deployments was not a significant problem at this site. Total respiration exceeded gross production at South Marsh; thus, the net ecosystem metabolism and P/R ratio indicated that this is a heterotrophic site (Figure 13). Temperature was significantly ($p<0.05$) correlated with gross production, total respiration and net ecosystem metabolism. Gross production and respiration increased as temperature increased, while net ecosystem metabolism became more heterotrophic as temperatures increased. Salinity was significantly ($p<0.05$) correlated with gross production and total respiration but not net ecosystem metabolism. Gross production and respiration were higher at higher salinity. Thus, the metabolic rates strongly followed a seasonal pattern with the highest rates during summer months and the lowest rates during the winter rainy season when temperature and salinity were low.

Table 12. Summary of metabolism data and statistics at South Marsh, 1996-1998.

South Marsh	mean	s.e.
Water depth (m)	2.0	
Net production $gO_2/m3/d$	1.00	0.05
Gross production $gO_2/m3/d$	3.16	0.09
Total respiration $gO_2/m3/d$	4.05	0.10
Net ecosystem metabolism g $O_2/m3/d$	-0.89	0.05
Net ecosystem metabolism g C/m2/y	-26	
P/R	0.78	
Statistical results		
Drift – paired t-test		
Gross production	ns	
Total respiration	ns	
Net ecosystem metabolism	ns	
Percent useable observations	88%	
Paired t-test on gross production and total respiration	$p < 0.001$	
Correlation coefficient	Temperature	Salinity
Gross production	0.35	0.23
Total respiration	0.38	0.22
Net ecosystem metabolism	-0.11	ns

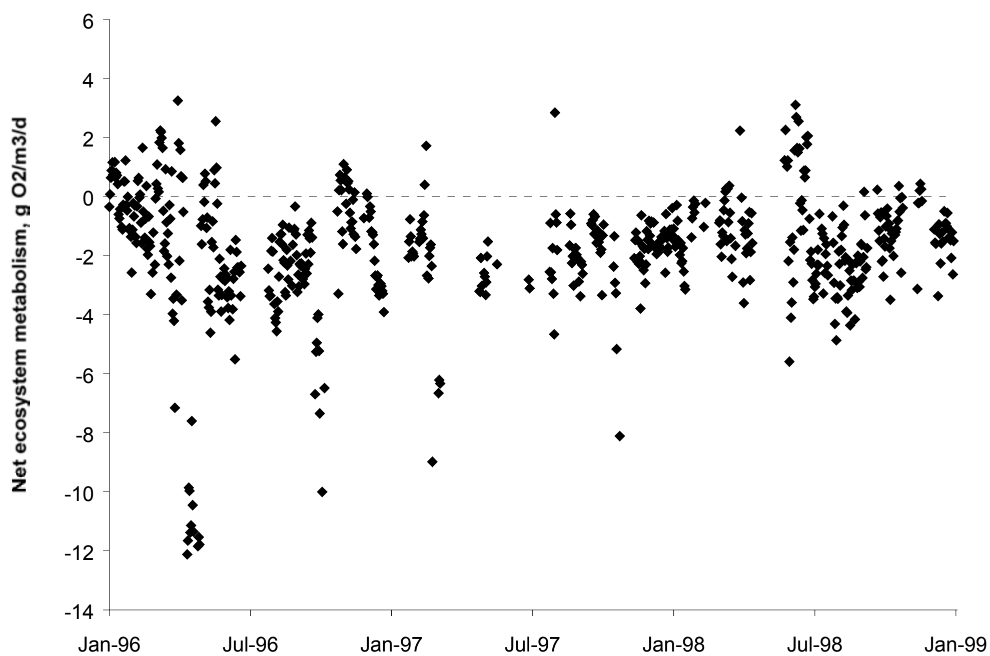


Figure 13. Net metabolism at South Marsh, 1996-1998.